CYBERNETICS AND SOME PROBLEMS OF PHILOSOPHY

THE stimulus of certain engineering problems such as the design of automatic gun controls and high-speed computing machines provoked a rapid consolidation of ideas derived from hitherto largely independent fields of inquiry, including pure mathematics, statistics, electrical engineering, and neurophysiology. The result was a science that, like other historical products, is both new and old—old in many of its component features but new in degree and manner of integration. Mr. Norbert Wiener brought this new development to general notice in the book strikingly called *Cybernetics*,[1] the name coined by him and his associates for the science of communication and control in animals and machines.

"Cybernetics" is derived from a Greek word for steersman, which is related to the Latin ancestor of our word "governor."[2] It is an apt name for a study that centers in the problem of automatic governors or controls. And if the movement had a symbol, it would probably be the old-fashioned fly-ball governor, which was pictured on the cover of the *Scientific American* when it devoted an issue to automatic controls.[3] Familiar since the eighteenth century, that device attracted no particular scientific attention[4] until discoveries along different lines brought into prominence the remarkable principles which it happens to exemplify with great simplicity. It may also be said that the peculiar nature of self-adjusting systems had been recognized and appreciated qualitatively by more speculative minds more than a generation before the advent of cybernetics,[5] which had to await a reasonably adequate quantitative treatment of such systems. By the present time, quantitative methods have been extended over the whole range of fundamental cybernetic subject matter, so that a new mastery of ideas and new suggestions for experiment promise many fruitful advances. As is the way with scientific ideas, these have philosophical interest. My purpose is to explain in the simplest possible way what is new in cybernetics in order that we may then consider what insights philosophers may obtain from this source.

From the point of view of general philosophy, the most important lesson of cybernetics is the explicit recognition that self-adjusting mechanisms cannot be understood solely in terms of the utilization of power or the transformations of energy, although of course these also are necessarily involved. If control is to be exerted over a given factor (*e.g.*, speed, temperature, phase difference, hydrogen ion concentration), the state of the factor to be regulated must be communicated somehow to the controlling mechanism, which otherwise would achieve adjustment only by chance. The governor, moreover, must react to the communication in such a way as to reduce to a minimum the deviation of the system from a certain state through the operation of negative feedback. Our simple flyball governor illustrates both these features in an obvious manner. When the engine, for example, to which it is attached speeds up, "information" concerning this change is communicated to the governor in the form of an increased rate at which it spins, causing the flyballs to rise higher and close the throttle correspondingly, so that the engine will tend to slow down again. When the engine, on the other hand, slows down, the balls drop lower and increase the engine speed by opening the throttle a suitable amount. A properly designed governor will thus keep the speed of the engine constant within comparatively narrow limits under normal conditions. Some of the power output of the engine is "fed back" into a throttle control that opposes any tendency to change speed. Such a feedback is "negative." But the flyball is the most important part of the device, because it mediates the control of the negative feedback by automatically "computing" a throttle setting adjusted to the speed of the engine as represented by the spin of the governor. Thus the flyball symbolizes a whole class of devices which belong among the most remarkable achievements of recent engineering: the great computing machines, both digital and analogue.

By stretching analogy a bit further we observe that automatic governors resemble animals in possessing "receptors" to obtain "information," a "brain" to "compute" appropriate responses, and an "effector" mechanism to carry them out. Conceived with sufficient lattitude, analogues to these items of animal equipment are by no means uncommon but may be recognized (or at least surmised) in a great many natural and artificial systems from the thermostatically controlled gas oven to the human being. Controls involving negative feedback appear to enter into the structure of any system sufficiently organized to be capable of acting as a whole because of mutual adjustment of parts, whether the system be a machine, a plant, an animal, or a society.

The communication of engine speed to flyball governor is accomplished by such simple mechanical means that its significance as communication easily escapes notice. But the practical importance of the problem of transmitting signals and the technical mastery of it during the last two or three generations needs no further comment than an allusion to telegraph, wireless, telephone, teletype, radio, television, radar, not to mention phonographs, sonar, guided missiles, and high speed computing machines. In all cases, the accurate sending and receiving of signals are subject to stringent physical limitations. And communication engineering, which is primarily concerned with accurate transmission and reproduction of signals, has found its problems related to the fundamental statistical characteristics of physical processes. Thus "information" has come to stand for a physical quantity, the measure of orderliness in a set of events. It does not imply cognition but is the negative of entropy,[6] the measure of disorderliness or "noise."

While the above exposition of cybernetic ideas makes no pretention to completeness, it has perhaps succeeded in emphasizing the main points. Of the greatest importance is the new idea of mechanism involved in those systems, of wide natural occurrence and inestimable technological promise, that automatically adjust themselves to variations in relevant aspects of their physical environment. That idea portends a change, perhaps far-reaching, in our approach to a variety of problems, and thus illustrates anew the power of ideas derived from science and engineering to expand the mind and alter established habits of thought. That is why cybernetics attracts the attention of philosophers; they must try to arrive at a balanced critical judgment of its larger implications.

It is not my intention to offer here a system of cybernetic philosophy or even a philosophy of cybernetics. There is more than enough to do just examining the bearing of the new ideas on a few well-worn subjects of controversy. In general we shall find that cybernetic ideas stand in a curious dialectical relation to traditional problems. It goes without saying that cybernetics is itself thoroughly mechanistic in spirit and intent, and its successes obviously win new ground for philosophical mechanism. On the other hand, it rehabilitates, one after another, a series of claims that tough-minded empiricists and materialists have customarily rejected. It makes mechanism subtler and more adequate to facts than formerly, but it weakens the reductionist prejudice against the efficacy of nonelementary realities. Cybernetics thus reinforces the tendency of recent naturalism to expand the conception of mechanism to fit facts of life and mind. It may help us in the end to grasp the way in which mechanisms serve the recognized purposes of higher intelligence. But that development still awaits the future. For the present we shall do well to look closely at claims voiced in the first enthusiasm of discovery. Let us, therefore, address ourselves to some specific issues on which cybernetic ideas bear.

It is appropriate to begin with a topic which Norbert Wiener has discussed, namely, vitalism. Having first developed the parallel between the automata of the present age and the living organism, both of which possess structures for receiving impressions, for performing actions, and for adjusting the latter to the former, Wiener goes on to show that the mechanisms of physiology and of these automata fall under the same physical theory, a theory indeed which belongs to statistical mechanics rather than to classical mechanics. Since output must succeed input, the past-future relation is fundamental; time has an irreversible direction for all such mechanisms (they cannot run backwards). "Thus," he concludes, "the modern automaton exists in the same sort of Bergsonian time as the living organism; and hence there is no reason in Bergson's considerations why the essential mode of functioning of the living organism should not be the same as that of the automaton of this type. Vitalism has won to the extent that even mechanisms correspond to the time structure of vitalism; but . . . this victory is complete defeat, for from every point of view which has the slightest relation to morality or religion, the new mechanics is fully as mechanistic as the old. . . . In fact, the whole mechanist-vitalist controversy has been relegated to the limbo of badly posed questions."[7]

Offhand dismissal of what may seem to have been a rather curious incident in recent intellectual history does not display the cybernetic contribution in the best light. It obscures what was legitimate in the question, however ineptly posed, and thus conceals the precise nature of the problem to which cybernetics may provide a superior answer. The vitalism controversy arose because men who studied the details of organic evolution and of individual development found the sweeping claims of nineteenth and early twentieth century mechanists unverified in detail. Bergson, whom Wiener particularly singles out for criticism, does not differ from Wiener in what he denies but in what he affirms. He saw that the evolutionary method of understanding living things had an essentially historical character at variance with the non-historical theorems of classical mechanics. He could detect no resemblance between the time of the living entity and the reversible "time" of classical physics. Time is more than a timeless variable for a being that is determined to action not by some immediate compulsion alone, but by the cumulative influence of its total past and by the insistent tendency of its vital processes. Thus he stressed memory and action against the "cinematographic" picture of change, which he attributed to the mechanist. In cinematographic time, novelty cannot arise. Each momentary state of things has its complete being in the moment and is completely accounted for by derivation from the immediately preceding state. It neither grows from roots in a significant past nor possesses freedom to generate a novel future.

That was the conception of process against which vitalism, as Wiener agrees, proved victorious. But the victory by no means awaited the advent of cybernetics. Ernst Cassirer's study of the history of the controversy among theoretical biologists in close touch with empirical findings shows that vitalism and mechanism ceased to represent "wholly dogmatic antitheses." The notion of purposiveness, with which some vitalists began, gave way to that of wholeness or organization as the distinctively biological category. The biologist had no further temptation to postulate an immaterial agency or "entelechy" to account for the peculiar phenomena of life. He did not have to look beyond the observable integration of various functions into the unity of an organism to some psychical or voluntary ground of organic teleology. Though he took for granted that all processes within the organic whole invite physico-chemical explanation, the organismic biologist, according to Cassirer, considered that organic wholeness and historicity of vital process could not be completely grasped as mere sums of causal chains. They could, however, be explored by different, more specialized methods.[8] A dogmatic antithesis of ultimate causes, mechanical *vs.* vital, was converted into a difference between two methods, a division of labor for research. In a sense, perhaps more profound than Wiener's, it was understood that the question of vitalism *vs.* mechanism had at first been ineptly put.

Thus far had informed thinking reached without the aid of cybernetics. But Cassirer's chapter on vitalism refers to no work published later than 1934, and if we read it with the wisdom of cybernetic hindsight, we perceive that it leaves the physics of "information" and communication engineering out of account. But if these have an outstanding contribution to make to biology, it will consist precisely in illuminating the theoretical conditions of any organization of a plurality of actual elements into integrally functioning wholes. If cybernetic theory is right, organization and wholeness require communication and mutual adjustment of parts within the whole as well as adaptation of the whole to circumstances by response to signals received from without. Cybernetics supplies a mathematically implemented theory of the regulatory physical mechanisms which make such wholeness materially possible. That is a new achievement, and its value is difficult to exaggerate.

Thus we may sympathize with Wiener in holding that cybernetics has assured to vitalism a victory which is, nevertheless, complete defeat, since "the new mechanics is as mechanistic as the old." The self-regulating device or "servomechanism" is as truly an automaton as any clockwork. If the functional wholeness of organisms, which is presumably peculiar to life, can be reduced to automatism, the ultimate winner seems to be philosophical mechanism. If this is so, then to say of the cybernetic contribution that it showed the question to have been badly put hardly goes far enough. If Wiener's confidence in cybernetic automata is justified, then the only real question ever at issue has been settled. It is hard to see how the question raised by vitalists could have been more clearly put in terms of ideas and information available at the time the controversy arose. The controversy, moreover, may be said to have greatly clarified the question, if we accept Cassirer's account, since it brought to the fore the very problem of organization about which cybernetics has something new to say. The question had not been badly put but badly answered, whether in terms of entelechies on one side or in terms of power engineering on the other. The vital issue emerged as a problem of communication and control, which can now be subjected to a varied and resourceful experimental attack with the aid of logically exact, formal theory.

On the other hand, it should not be overlooked that, just as a new concept of mechanism had to be developed in order to account for the behavior of certain complex wholes, the cybernetic mechanism may not itself account for all modes of higher organic behavior. It is not clear how far Wiener himself cares to go. He seems chary of the label "materialism,"[9] although no one can doubt that the line from Descartes' animal automaton runs through La Mettrie's machine man and Jacques Loeb's animal tropisms[10] direct to Wiener's subsumption of mechanical, animal, and human behavior under the same theory. If this is the last word, then we must revise Pope, for henceforth, the best study of mankind will be Eniac. Even so, Wiener does not hesitate to speak of "ruthless operators," of "knaves" and "fools," of "lies," "exploiters of gullibility,"[11] "slave labor," "hucksters" (with disparagement), and he proposes the ideal of "a society based on human values other than buying and selling."[12] What meaning these expressions can have in a world of automata is impossible to say. For that matter, what *meaning* can anything have for an automaton?

With this question we pass from *life* to *mind*. The dialectical situation remains much the same. The idealistic insistence on the uniqueness of mind or spirit has always found its chief support in the activities of scientific understanding, artistic creation, moral achievement, and religious devotion, to which the reductionist expedients of materialists have never in the past proved adequate. The strongest trend of philosophical thinking in this century, nevertheless, has rejected the "dogmatic antithesis" of mind and matter, and has tried in various ways to reconcile them in the all-embracing unity of "Nature." Most philosophers of our generation take for granted that psychical processes are inseparably associated with physical processes and require them in order to exist, but a decided lack of clarity prevails about the *kind* of physical processes required. Here, again, cybernetics comes up with novel and experimentally useful suggestions. Here, again, the older forms of materialism turn out to be mistaken, but mistaken in a way that yields the anti-materialist small comfort.

With characteristic alertness to new scientific developments, F. S. C. Northrop has commented on some cybernetic suggestions respecting the higher activities of man.[13] Cybernetics, he says, has made a place in natural science for the interpretation of thinking, universals, purposes, and the control of individual human behavior by cultural norms, and has, moreover, provided a firm scientific support for the commonsense belief in the efficacy of human purposes in determining concrete events in nature. He considers this achievement a conclusive scientific refutation of every materialism, Marxist or otherwise, that assigns to ideas and social theories a dependent, epiphenomenal, or parasitic status in the physical world. Ideas, he says, have been shown to exist as physical processes no less fully verifiable than other physical processes and no less capable of producing physical consequences in outward behavior. But, he adds, this refutation of materialism cannot be turned to the advantage of other traditional philosophies, because it refutes them also, every one of them, whether dualistic, mentalistic, or positivistic.[14] For cybernetics casts doubt on an assumption on which Northrop considers traditional philosophies to have agreed, the assumption, namely, that natural science cannot find room for purposes, universals, and social norms and ideals among its objects. Cybernetics apparently saves these phenomena without an ultimate distinction between mental and physical processes, because it has available a previously unrecognized distinction between two types of physical automata. As in the case of vitalism, anti-materialism wins, but wins a Pyrrhic victory. The older materialism had long since been discredited by the breakdown of classical concepts of matter and mechanics, but the statistical conceptions of cybernetics leave no more room for mind than did the old-fashioned theories.

On the other hand, the resultant view restores, as was noted, several notions to scientific respectability which look distinctly odd in a mechanistic context. Perhaps the most striking of them is the notion of form, which is restored to almost Aristotelian prominence as a factor to be reckoned with. Northrop was, I believe, among the first to point out that mechanisms which adjust their behavior in predetermined ways to the *pattern* of the input react to the universal in the particular event rather than to the particularity of the energy in the event.[15] Recalling Aristotle's word about perception,[16] we may describe such a machine as receiving the *form* without the *matter*. One consequence of this is memory, which works by freeing the universal from dependence upon a particular occasion; and, according to the cybernetic analogy, any device such as a punched tape, photographic film, or phonograph record, performs the storage function essential to memory. The notion that memory involves some sort of enduring "impression" made on the mind by sense perception is certainly as old as Plato's simile of the wax tablet,[17] and the notion that it depends on some sort of physiological trace cannot be younger than Hobbes' "decaying sense."[18] But the beginnings of an empirical treatment of the physiological traces belong to the recent past. The details, about which much remains to be learned, need not detain us.[19] It is in general sufficient to recognize that progress in understanding has come about by interpreting the problem of memory as one of storing information (form or pattern) and making it available for use, perhaps by embracing it at some point within a regenerative loop.[20] Thus the adroitness of an experienced man reflects his "much memory"[21] in the form of circuits established in his nervous system by past experience. Empirical universals, ideas, concepts, or defining forms have apparently become hard physiological verifacts as well as familiar objects of psychological commonsense. As

Northrop has emphasized, the old difficulty of explaining how ideas can modify physical behavior has disappeared, since ideas have a physical embodiment capable of influencing decisively the behavior of an organism. Not much energy is involved, but there is quite enough, since the most important aspect of the nerve cell is not its own power but its connections.

If perception consists in response to, and memory in conservation of, pattern or form, it follows that universals have a status and efficacy quite at variance with the customary nominalism of empiricism, materialism and naturalism. Cybernetics goes far towards restoring the formal cause to scientific respectability. "Information," says Wiener, "is information, not matter or energy."[22] Now it is a cardinal principle of cybernetic doctrine that some mechanisms respond to "information" rather than to the material or energetic vehicle which carries it. The efficient determining cause is the information or type of order, and this is not the same as the material cause of the modern era. Of course, "information" cannot exist without some physical embodiment, or form without matter. But one cannot be reduced to the other. A complete account of the behavior of automatic controls, therefore, must cover both.

The great computing machines having been designed to carry out logical and mathematical operations of the kind men perform, it is not surprising to find that the brain is assumed to function like the digital computers.[23] Warren S. McCulloch and Walter Pitts showed that neural networks of regenerative loops possess, as Northrop puts it, all the formal properties of the logic of *Principia Mathematica*. In a word, a logical calculus lies innate in the structure of the human nervous system, so that it can perform all deductive operations symbolized in modern logic (including, of course, Aristotelian logic as a restricted case).[24] McCulloch and Pitts have, moreover, shown that the human brain has the properties required, in principle, to compute any logical consequence of its input.[25]

So much for the theory. In practice, the computing machine and the brain will exhibit limitations inherent in their structure. Wiener has briefly alluded to the possibility that the mechanics of the brain may limit the powers of thought. "The *machina rationatrix* is nothing but the *calculus rationator* of Leibniz with an engine in it; and just as modern mathematical logic begins with this calculus, so it is inevitable that its present engineering development should cast new light on logic . . . the study of logic must reduce to the study of the logical machine, whether nervous or mechanical, with all its nonremovable limitations and imperfections."[26] This is not, as Wiener points out, the same thing as "psychologizing" logic, but only asserts that logic can meaningfully "contain nothing which the human mind—and hence the human nervous system—is unable to encompass."

Now, this cybernetic doctrine of the function of the brain in thinking supplies unwitting support to a kind of functional *a priorism*. If thinking is nothing but the functioning of the computing machine of the brain, it is limited to forms of operation permitted by the electrical network of the nervous system. The possible functions of thought are "built in," and though capable of specific modification by "input" (sense-data, for example), they remain generically fixed. The laws of logic are grounded not only in ontology but, precisely, in the electrical engineering of the brain. The universals previously mentioned, that enter into reverberating circuits for use are empirical universals; but the forms of the logical operations of the brain express its structure, independently of sense experience and learning. The forms are in that respect a rational *a priori* akin to Kant's.

In a sense, this *a priori* may even be described as synthetic, although the adjective would hardly come to mind save for historic reasons. Logically, the results of a computing machine are analytic consequences of the premises fed into it. But the construction of the machine itself combines its diverse operations into a functional unity. Similarly the unity of the mind is functionally synthetic and may be presumed to require structural unity-in-diversity of the nervous system, considered as an electrical network with certain describable properties. Kant intended in the transcendental deduction of the categories to identify the basic operations of the understanding by contrasting its "output" with its "input"—objective knowledge (science) with bare sense perception. Neurophysiology may now also study the electrical mechanisms which produce some of the observed results. Once more we find cybernetics confirming older, non-materialist speculations but at the same time taking new ground for mechanism.

Comparison of this physiology of reason with Kant's transcendental analytic is a delicate matter. We should guard against exaggeration. My point is simply that in following out the mechanist ambition to physiologize the mind, the cyberneticist inadvertently supports the ancient rationalistic conviction that the forms of reason are native to the mind independently of experience. Yet, though Kant would presumably agree that scientific psychology as well as brain physiology must be rigorously deterministic (not to say mechanistic) in order to be objectively valid, he would not precipitately identify scientific thinking with the objects thought about.

Nowhere, however, is the cybernetic contribution more striking than in the treatment of purpose, which is behavioristically defined and then explained on the model of the servomechanism. About a decade ago, Arturo Rosenblueth, Norbert Wiener, and Julian Bigelow discussed the topic in a paper rich in ideas.[27] They offer definitions of "purposeful" and "teleological" behavior in strictly descriptive terms that apply equally to machines, organisms, and men. Anything exhibits purposeful behavior if it may "be interpreted as directed to the attainment of a goal," the goal being thought of as "a definite correlation in time or space with respect to another object or event."[28] Nonpurposeful behavior is "random." Because it has a direction, purposeful behavior indicates the presence in the behaving entity of a control responsive to the goal, just such control as the automatic governor achieves through the negative feedback. The authors suggest that purposeful behavior always depends at some point on a servomechanism.

Purposeful behavior is termed "teleological" when it is "controlled by error of reaction" (via negative feedback) "in the course of the behavior."[29] For example, an acoustical torpedo behaves teleologically, because it continually adjusts its course to signals reaching it from the target.

Rosenblueth, Wiener, and Bigelow draw two philosophically significant conclusions from reflection on the mechanisms which implement purpose: (1) The opposite of teleology is not determinism but non-teleological determinism; and (2) animals and machines differ not in behavior but "functionally," that is, in the materials and structures which function to produce the observable behavior. Specifically, machines are mostly metallic, with simple molecules; they exhibit large differences of potential, rely on electronic conduction, permit rapid mobilization of energy. Organisms, on the other hand, are colloidal, with large molecules; they depend on ionic conduction, have a more uniform distribution and less rapid mobilization of energy. Organism and machine differ also in the method of achieving scope and flexibility. The former does so by multiplication of simultaneous effects, as in the eye with its large number of cones and rods; the latter multiplies successive effects, the television receiver, for example, forming an image in a single "cone" by scanning many millions of signals per second.[30]

Though these so-called functional, or internal, differences between animals and machines are specific, they are not generic, all alike being physical and even mechanical in the larger sense, and they do not differentiate the behavior of one from that of the other. Even machines behave "teleologically," according to the cybernetic view, in precisely the same sense as animals and men.

Thus we return to the first of the two conclusions mentioned above, which is that teleology not only is consistent with mechanism, but even requires it, since "purposeful" and "teleological" apply descriptively to behavior only, whereas mechanism refers to its functional basis. Behavior and function go together—purposeful behavior and controlled function. Teleology *vs.* mechanism presents a false antithesis, the one being descriptive of behavior and the other explanatory of it. "Purposefulness, as defined here, is quite independent of causality, initial or final."[31] "Causality," we are told, means a one-way, irreversible functional relationship. In the explanation of behavior we rely on mechanisms, for statistical mechanics is still deterministic, and chance is not moral freedom. "Tyche," Wiener observes, "is as relentless a mistress as Ananke."[32]

Rosenblueth, Wiener, and Bigelow go yet farther. They suggest that teleological behavior which is "predictive" (as when a gunner shoots ahead of a flying duck) may fittingly be classified as "intelligent." The more complex the prediction is, the more intelligent is the behavior.[33] Functionally, intelligent behavior requires a computing machine capable of performing on the past of a curve the operations necessary to obtain valid predictive extrapolations. The torpedo that pursues a loud noise, the flower that faces the moving sun, the moth that dies in the flame, the human eye that is captured by the flickering glare of electric signs, these all exhibit simple tropisms. On the other hand, a radar-directed anti-aircraft gun and a duck hunter act intelligently. Both form simultaneous estimates of the target's and the missile's probable course. On a given occasion, the gun may well behave more "intelligently" than the hunter.

As a final, somewhat ironic comment on the cybernetic notion of purposeful mechanisms, observe that the mechanist cannot now reject *a priori* the possibility of cosmic teleology —that "through the ages one increasing purpose runs." "Purpose" will obviously not have theistic overtones as it did for Tennyson. But there is no *a priori* reason why cosmic systems may not include negative feedbacks and hence behave "purposefully" in the cybernetic sense, or why the universe could not form a teleological whole, although *a posteriori* evidence for holding that it does may be inconclusive, if not lacking. Biologists, historians, and philosophers have often thought they could detect a direction in events—an "upward" trend in evolution, a (Hegelian or Marxist) dialectic of history, a "nisus toward totality," an emergent deity. But in this case as in all others, the goal toward which cosmic process may be interpreted as tending would be the outcome of an automatic process entirely devoid of value connotation.

While it is important to appreciate the value of the cybernetic contribution to several philosophical theories, which were rapidly reviewed, it is not less important to avoid expecting more than can be delivered. Cybernetic ideas have not introduced a genuinely new alternative into philosophy. Crude dualisms of mind-body, organism-machine, teleology-mechanism have long been rejected in favor of some sort of reconciliation—though on *that* point opinions have differed. Cybernetics has had something to say that is worth listening to with close attention, but it has as yet approached its task with mechanistic presuppositions,[34] which conceal from view the range of human experience that always has made the notions of mind and of purpose both important to philosophers and puzzling. That kind of omission normally accompanies scientific specialization and is amply justified by results. But methodological convenience may become dogmatic bias if taken up uncritically into the philosophic quest for comprehensive adequacy.

To be philosophically adequate, a theory must be able to account for its own existence, but that is what cybernetics cannot do if it is converted forthwith into a comprehensive theory. Cybernetics accounts for many things but not for itself, for the science, the knowledge, of cybernetics. The cyberneticist has much to say about the brain and other mechanisms, but not about *understanding* the brain. He easily reconciles teleology and mechanism, as long as he does not mention the only significant purpose which enters into the picture. He can explain "memory" but not "remembrance of things past."

Consider, for example, the treatment of teleology and mechanism. An apparent reconciliation of these is brought about by defining them in terms of a methodological distinction between behavioristic and functional study. The former concerns "any change of an entity with respect to its surroundings"; the latter investigates "the specific structure and intrinsic organization of the object."[35] The former is descriptive and non-causal; the latter is explanatory and causal. They are, therefore, complementary to one another rather than antithetical.

This would be very convincing if the argument did not begin with a stipulated definition of "teleological behavior" which includes as its differentia the functional notion of negative feedback in the course of behavior. By definition, no opposition between teleology and mechanism goes deeper than a shift of the investigator's center of interest, for it is clear that whether an account is behavioristic or functional depends on what the investigator has selected as delimiting the object of study and not on any ultimate difference of method. The functional analysis of an entity describes the behavior of some of its constituents; the description of the behavior of an entity exhibits it as a functional part of some more inclusive system. The two accounts supplement one another without any alteration whatever in fundamental point of view, which seeks and finds only physical automatisms, causal and statistical. This, of course, does not in any sense constitute an objection to cybernetic analyses and stipulated definitions. But philosophically, the only lesson to be drawn from them is that if you begin with mechanism and admit nothing else along the way, you will end with mechanism. And that is a truism. A choice of definitions alone will not prove that the purposiveness which men sometimes exhibit is *nothing but* the automaton's "purposeful behavior."

If the "nothing but" is assumed right down the line, then bare mechanism is a foregone conclusion, and Northrop's celebration of the demise of epiphenominalism would appear to be somewhat premature. On the other hand, Wiener himself unquestionably talks quite often as if mechanism is far from the last word. "He who studies the nervous system cannot forget the mind," he writes, "and he who studies the mind cannot forget the nervous system."[36] But if mind is nothing but nervous system in action, there would be nothing to forget while studying the nervous system. Actually, cybernetic research relies constantly on what the cyberneticist knows about the mind before he begins to study the brain. He knows what it means to be an intelligent, conscious being, engaged in various modes of purposive activity, including empirical and mathematical enquiry. The record of his steady reliance on this dimension of experience is so written across the vocabulary of cybernetics that he who runs may read. In the history of modern science there is scarcely a parallel to its brazenly anthropomorphic terminology—"information," "memory," "prediction," "purpose," "intelligent behavior," and even "will"[37] and "conscience,"[38] "valuation" and "choice."[39] In an unguarded moment, while commenting on computing machines that can also detect and erase errors in their "memory," McCulloch wrote: "Consequently, *they* may *prefer* magnetic tapes to punch cards,"[40] as if the machines cared or could tell the difference. A slip of the pen, no doubt; but how eloquent!

A theory developed in connection with the designing of machines to perform some of the functions of the human mind should not forget other functions which it has not copied. The human brain may indeed work like a computing machine; the machine, after all, was made in its image. But the brain does something which artificial machines apparently come no closer to doing than ever, namely, support a conscious system which takes notice of the results of operating upon the "input," knows something about *how* the results were obtained, and recognizes *objects* which transcend the results.[41] This involves explicit recognition of the past *as past* (not simply as stored "form") and anticipation of the future *as future.* A machine may "learn," "forget," "recall," "predict," "evaluate," "choose," and in many ways embody an undirectional time; it never is *aware* of its input as sense data, never questions, infers, understands, never prefers, aspires, or grows in range of insight. It can "select an optimum alternative," but it cannot care about it, much less criticize its standard of selection or conceive of any other, not to say a higher one.

There can be little doubt that many mental operations are unconscious, suggesting dependence upon an automatic apparatus, in satisfactory agreement with cybernetic analogies. Even the creative work of genius corresponds to this pattern, as does the familiar prudential practice of "sleeping on" a difficult decision. But no unconscious machine can recognize the value of a novel combination of elements that suddenly comes alive with unsuspected significance. As for that matter, the work of the automaton remains aimless and meaningless unless at some point it receives conscious recognition, direction, appreciation. Every calculating machine requires a human operator to transform the output (even though it be "information" rather than matter or energy)[42] into cognition. An indispensable feature of every computing machine is a mathematician (if only a bookkeeper) at the input and a mathematician at the output to understand the results as answering *his* question. Cybernetics tends to treat the human worker as a needlessly complex device for regulating a machine in a fashion that better designed servomechanisms could do more efficiently. But we must understand that from the point of view of a mind, the machine is an extension of its bodily instruments of purpose and action. Far from enabling us to dispense with mind as a problem, the complex cybernetic mechanisms require the whole history of western science to account for them.

To forget the man who makes and uses machines for his own ends is to forget the one distinctively purposive being available for study. The only purpose which the acoustic torpedo exhibits as it runs its "single-minded" course is the destructive intention which made and fired it. It is all one to the torpedo whether it reaches its "goal," wildly oscillates between extreme deviations from its proper course, or turns back and demolishes the vessel that fired it. It has no purpose; its goal is not *its* goal. It is an automaton designed for human purposes. There are in nature similar automatisms that no man made. But if nature is all mechanical, why should there not be mechanisms of many kinds, including self-regulating systems? What forces us to inject the notion of purpose into the situation? The heliotrope turns toward the sun, because perhaps that mechanism favored survival. But where is a purpose there, unless we attribute to the plant an *endeavor* to survive? But "endeavor" is not a concept of mechanics.

Perhaps it may be suggested that the mechanism *is* the purpose: "Now, the purpose of voluntary acts is not a matter of arbitrary interpretation but a physiological fact. When we perform a voluntary action, what we select voluntarily is a specific purpose, not a specific movement."[43] So be it. What then is the voluntary act of selecting a purpose? And is a purpose as a physiological fact a purpose *before* it is selected, or is it only a potential purpose? Is the selective act a higher purpose automatically "selecting" a lower, or is it in some sense the man's whole character expressing and shaping itself? Is it the integral man seeking to give meaning to his individuality under the specific circumstances provided by a particular occasion?

To questions of this kind, cybernetic authors do not attempt answers. Cybernetics piles up the evidence against a crude materialism, which has long been discredited. But it leaves the status of mind or mentality in obscurity. Either consciousness, attention, the awareness of being a purposive activity, the knowledge of objective facts, insight into a human world about us, and appreciation of significant form make a difference or they do not. If they do, then cybernetic description of outward behavior and physiological function sketches an incomplete picture of human nature. Anybody who may be tempted to doubt this conclusion would do well first to account for cybernetic science itself without any appeal to minds or mentality capable of insight, foresight, understanding, intention, doubt, and rational satisfaction,—in a word, let him begin with an explanation of how there can be science without cognition.

Nobody would deny that the individual requires mechanisms when he thinks as well as when he acts. Yet the mind recognizes problems, is anguished by ignorance, and has a concern for the continuance of its own individuality and for the prosperity of its kind, and these facts have no analogues in the behavior of any *known* mechanism for automatic control. The computing machine has no problems of its own. The thermostat, the gun pointer, the automatic pilot—these react to the "information" at hand and never doubt its sufficiency. The torpedo will guide itself by "error of reaction" but never by the wisdom of its plans. A moth's self-immolation makes an uncanny impression on us, because its feeble individuality is so dominated by its phototropic automatism in the presence of a flame.

An individual able to know its world and itself to some degree can see itself within a cybernetic context and hence can choose to act, not merely through a so-called "purpose" tripped by impulses flowing in upon it from without, but in the light of its understanding. Such an individual, moreover, discovers he can bind himself by the conception of a justice that embraces all men, and thus can subordinate his life to a free possibility nowhere empirically verifiable as an actuality in human relations. An individual of that kind is teleologically free in a quite distinctive sense on which servomechanisms *alone* throw no light whatsoever. He intervenes decisively in the unfolding adventures of mechanical systems; through him or in him does conscious and enlightened purpose emerge in the aimless monotony of the physical world.

At some stage, physical systems seem to embark upon a new career, and the value of utility becomes a determining factor in events. Not merely the quantity and not merely the pattern of energy, but the value of it in what for a century has been romantically called the "struggle for survival" has to be taken into account. In addition to the numerical values of physical description, the biological value of survival is required for the scientific understanding of life. At that level, the individual begins to count and to impress its own demands upon the streaming transformations of energy. Reaction, no doubt with the aid of negative feedback, has become adaptive response. But again, achieved organization reaches into a new dimension with the mentality that looks all round, and seeing itself within a world, not only responds but takes the initiative and *acts*. Through this action there occasionally comes into existence a goodness, both original and fructifying, that forms the core of man's concern.

The range of experience to which these remarks allude is one that the new automatism, like the old, leaves in darkness. That is not surprising. Though indeed a significant advance in our knowledge of physical systems, cybernetics offers no new alternative to philosophy. But we may be grateful to it for stimulating fresh thought about long-vexed questions and for bringing us perhaps closer to a new and more satisfying hypothesis about the relation of life and mind and mechanism. We need a basis for closer agreement between those who are concerned with behavior and those who are concerned with responsible action.

JAMES STREET FULTON

NOTES

1. New York: John Wiley and Sons, 1948.
2. Cf. Wiener, *Cybernetics,* p. 19.
3. September, 1952.
4. An exception, cited by Wiener (*ibid.*), is a paper by Clerk Maxwell in *Proc. Royal Soc.,* March 5, 1868.
5. Stevenson Smith anticipated many cybernetic ideas as early as 1914 in a remarkable paper, "Regulation in Behavior," *Journal of Philosophy,* vol. XI, no. 12, to which Richard Taylor directed attention in "Purposeful and Non-Purposeful Behavior," *Philosophy of Science,* vol. 17, no. 4 (Oct., 1950), p. 331, n. 10. Smith himself refers to the principle that "a system tends to change so as to minimize an external disturbance" as "W. D. Bancroft's law," which was presumably generally known at the time. Among other examples of "auto-adjustment" Smith discusses "negative regulation," in which "the deviation towards instability has come to be the cause of its own remedy." (p. 323) This is an apt description of what Wiener, but not Smith, considers "teleological" behavior. Taylor also cites an article by R. B. Perry, "Purpose as Tendency and Adaptation" *Philosophical Review,* vol. 26, no. 5, pp. 447ff. Dewey's famous discussion of the reflex arc was a still earlier recognition, though rather obscure, of something akin to the negative feedback circuit of cybernetics: "The Reflex Arc Concept in Psychology," *Psychological Review,* vol. III (1896), pp. 351-70. Only recently, however, did these qualitative ideas receive promising formal expression.
6. Cf. *Cybernetics,* p. 18.
7. *Cybernetics,* p. 56. Chapter I as a whole is relevant.
8. Ernst Cassirer, *The Problem of Knowledge* (New Haven: Yale University Press, 1950), Ch. XI.
9. *Cybernetics,* p. 56.
10. The tropism of Loeb and his teacher, Julius Sachs, is an obvious

example of response controlled by negative feed-back. According to Cassirer, Sachs held that we should "treat everything which at first sight looks like independent activity and development as a complex of interacting tropisms, each one realizing itself in a purely mechanical way and being explicable by strictly mechanical laws." (*Op. cit.*, p. 206.) If for "tropism" we read "servomechanism" and interpret laws in the sense of statistical rather than classical mechanics, we have the cybernetic position.

11. These expressions will be found in *Cybernetics*, pp. 185-6.
12. And these on pp. 37-8.
13. F. S. C. Northrop, "Ideological Man in His Relation to Scientifically Known Natural Man," in *Ideological Differences and World Order*, ed. F. S. C. Northrop (New Haven: Yale University Press, 1949), pp. 407-427.
14. F. S. C. Northrop, *op. cit.*, p. 413.
15. *Op. cit.*
16. *De Anima*, II, 424a17 ff.
17. *Theaetetus* 191D.
18. *Leviathan*, Ch. II.
19. Cf. Warren S. McCulloch, "The Brain as Computing Machine," *Electrical Engineering*, June, 1949, p. 494. Another account by the same authority is to be found in the Hixon Symposium at the California Institute of Technology, published as *Cerebral Mechanisms in Behavior*, ed. L. A. Jeffress, 1948. The discussion by other members of the symposium brought out certain difficulties in McCulloch's theory.
20. Cf. McCulloch, *op. cit.*, p. 494: "Every other form of memory is only a surrogate for reverberating chains."
21. The allusion, of course, is to Hobbes, but one may also compare Aristotle, *Post. An.* II, 100a4 ff.
22. *Cybernetics*, p. 155.
23. Cf. the previously cited paper of Dr. McCulloch. It should be noted, however, that Wiener denies the exactness of the analogy between brain and computing machine. The brain is never completely "cleared" but is permanently modified by previous experience (input). It is analogous to a computing machine in the course of a single run only. (*Cybernetics*, p. 143).
24. Northrop, *op. cit.*, pp. 415-416. The fundamental paper of McCulloch and Pitts is "A Logical Calculus of Ideas Immanent in Nervous Activity," *Bulletin of Mathematical Biophysics*, vol. V, (1943).
25. McCulloch, *op. cit.*, p. 493. McCulloch and Pitts not only applied the calculus of propositions to brain functions but succeeded in introducing both logical quantifiers and functions at one stroke by noting that the regenerative loop "preserves the figure of the

input but no longer refers to one particular past time." (P. 494) It refers only to *some* past time. McCulloch regards the relevance of a logical calculus as the differentia distinguishing communication engineering from physics. He describes neurophysiology, therefore, as a branch of engineering!

26. *Cybernetics*, p. 147.
27. "Behavior, Purpose, and Teleology," *Philosophy of Science*, vol. 10, No. 1 (Jan. 1943), pp. 18-24.
28. P. 18.
29. Pp. 19-20.
30. P. 22.
31. P. 23.
32. *Cybernetics*, p. 49.
33. "Behavior, Purpose, and Teleology," pp. 20-21.
34. In explaining why they have used such terms as "purpose" and "teleology" in connection with machines, Norbert Wiener and Arturo Rosenblueth have said it was "to emphasize that, as objects of scientific inquiry, humans do not differ from machines." ("Purposeful and Non-Purposeful Behavior," *Philosophy of Science*, vol. 17, no. 4, (October, 1950), p. 326.)
35. "Behavior, Purpose, and Teleology," p. 18.
36. *Cybernetics*, p. 26.
37. Cf. Warren S. McCulloch, *op. cit.*, p. 493: "Any computing machine which can detect a discrepancy between what it calculated and its actual output may be said to have a will of its own."
38. ". . . the capacity for maintained worry, known in the terminology of another profession as the *Conscience*." *Cybernetics*, p. 173.
39. See, for example, Wiener's discussion of machine-played chess, *Cybernetics*, pp. 193-194.
40. McCulloch, *op. cit.*, p. 493. (My italics.)
41. The study of Husserl would probably repay anyone seriously interested in the complex mental activities required for consciousness of a transcendent object, though his approach is perhaps rather remote from the context of behavior.
42. "The mechanical brain does not secrete thought 'as the liver does bile,' as the earlier materialist claimed, nor does it put it out in the form of energy, as the muscle puts out its activity. Information is information, not matter or energy." (*Cybernetics*, p. 155.) But "information" is "negative entropy," not thought. The simplest way of putting the truth is that the mechanical brain does not produce thought at all. It produces patterns in which a mind can read a meaning. The machine produces no thought but in a mind.
43. "Behavior, Purpose and Teleology," p. 19. Cf. McCulloch, *op. cit.*, p. 493: "We intend, they [servomechanisms] act."